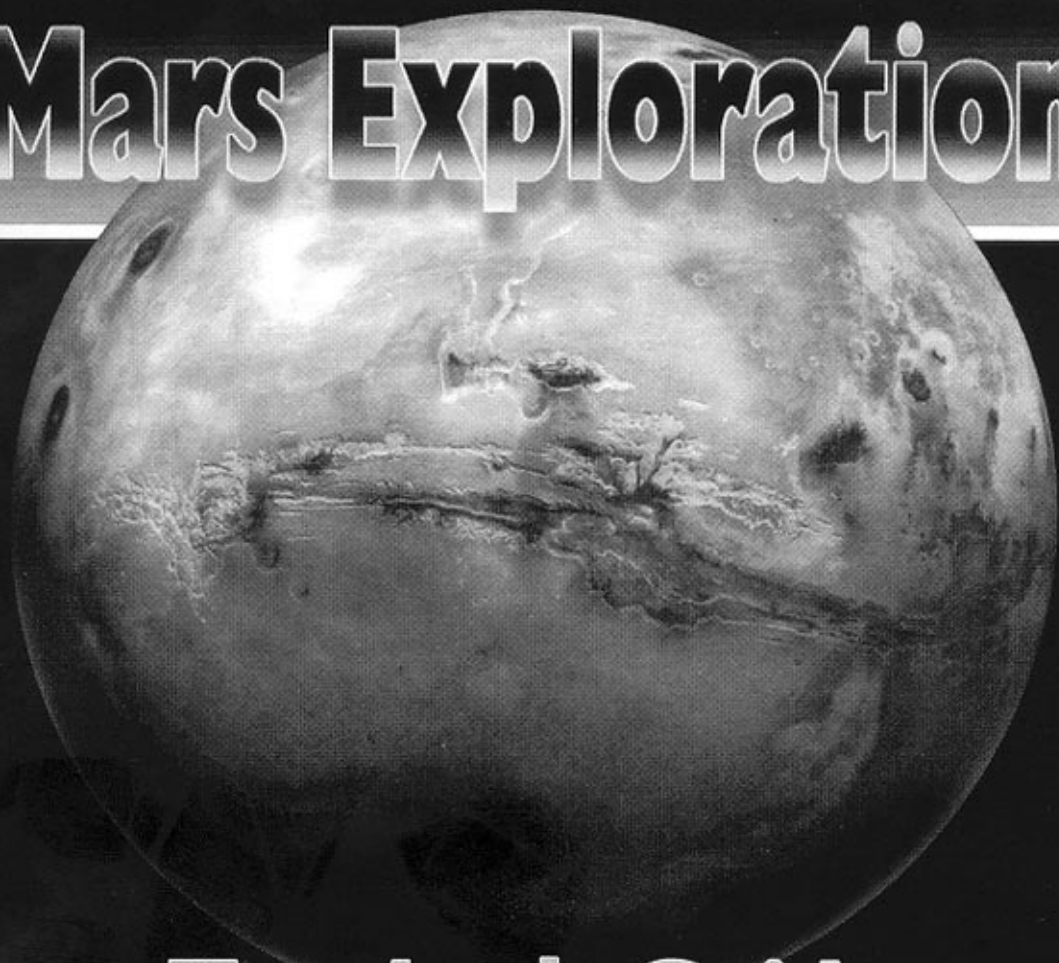


**MARS
EDUCATION
PROGRAM**

Mars Exploration



Teacher's Guide to Getting Started in Mars Exploration

Jet Propulsion Lab
Mars Exploration Education and Public Outreach Program

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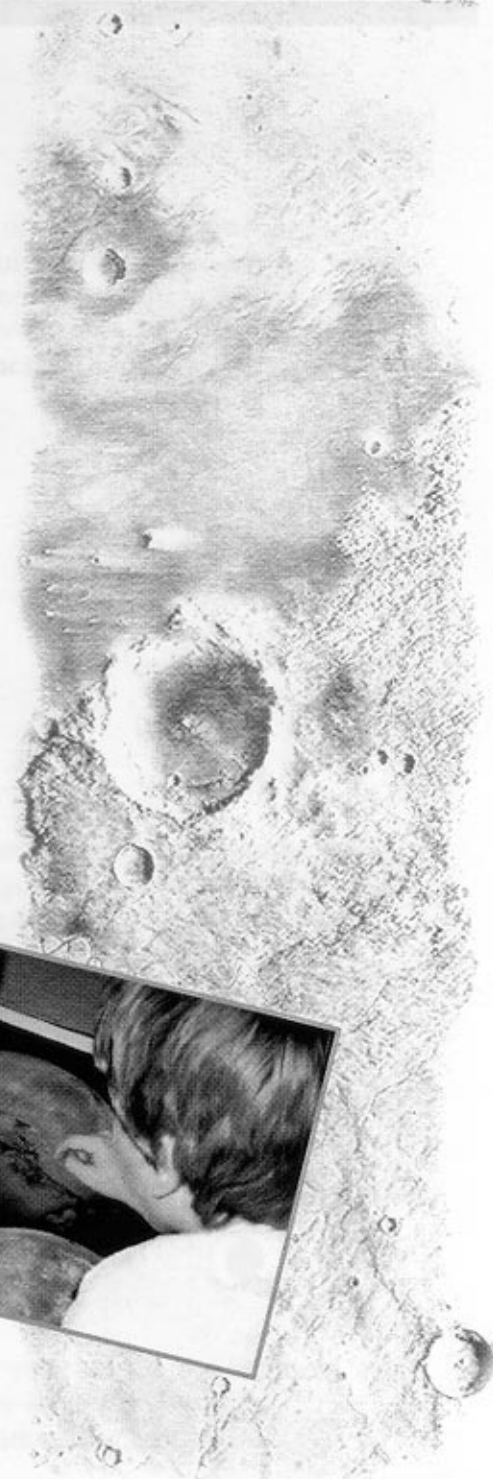
Welcome to the Mars Education Program



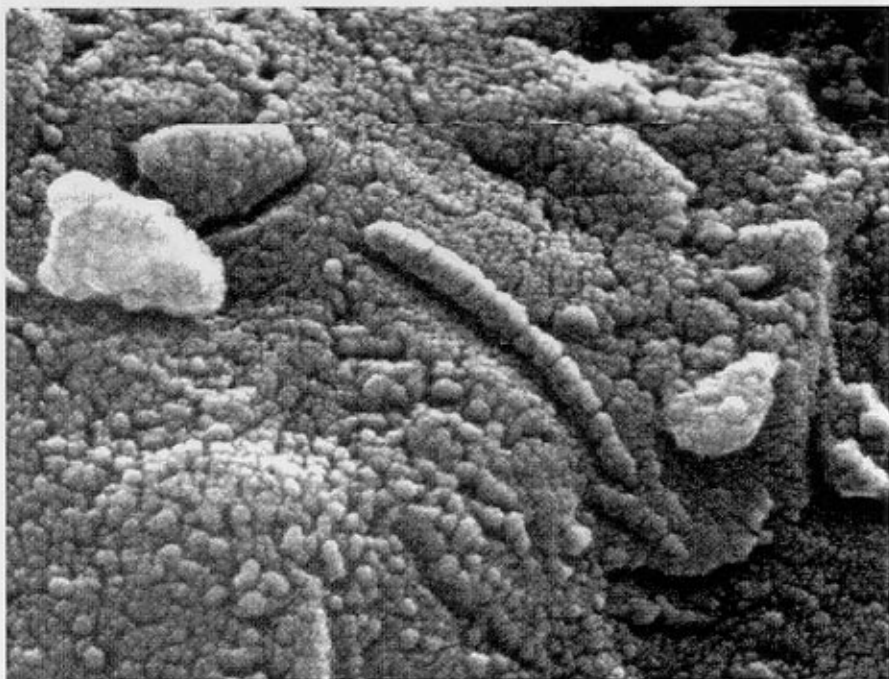
Mars is the focus of an exciting, new ten-year series of NASA planetary exploration missions. Mars also provides a wonderful opportunity for some powerful classroom learning experiences.

The Mars Education Program will help you engage your students in hands-on, inquiry-based learning, provide a context for learning about both Mars and Earth, and provide a window on student misconceptions.

The Mars Education modules were funded by the Mars Exploration and Education Public Outreach Program, at NASA's the Jet Propulsion Laboratory. The modules were developed and field tested by a team of educators and scientists to make sure that they are both scientifically accurate and educationally powerful. The modules will be improved on an on-going basis, based on teacher feedback and on new discoveries as Mars exploration advances over the next decade.



Mars is a Fascinating Planet!



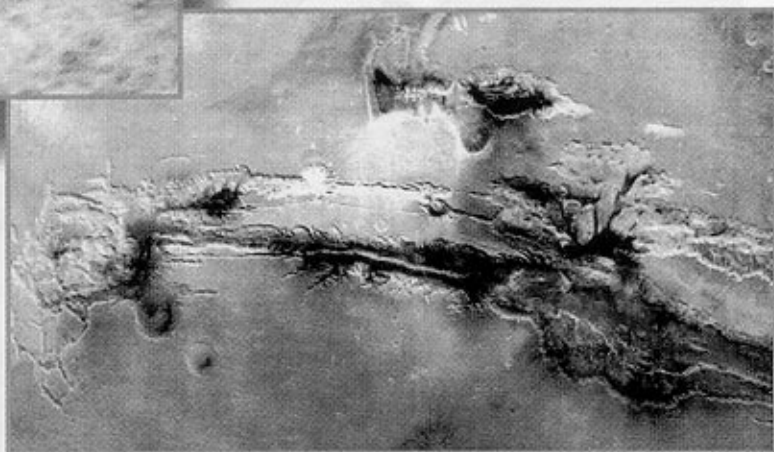
Scientists believe that this object might be a Martian microfossil, possibly the remains of primitive life from ancient Mars. Scientists used advanced technologies to examine a 4.5 billion year old rock that was blasted off Mars millions of years ago, traveled through space and landed in Antarctica. This is the strongest evidence ever found of life on another planet.

It raises profound scientific and philosophical questions. Are we alone as sentient beings in the Universe? Was ancient Mars covered with water and teeming with early life? Is there still life on Mars, perhaps near underground reservoirs of water and minerals? What is "life"? And it has put Mars high in the public consciousness.

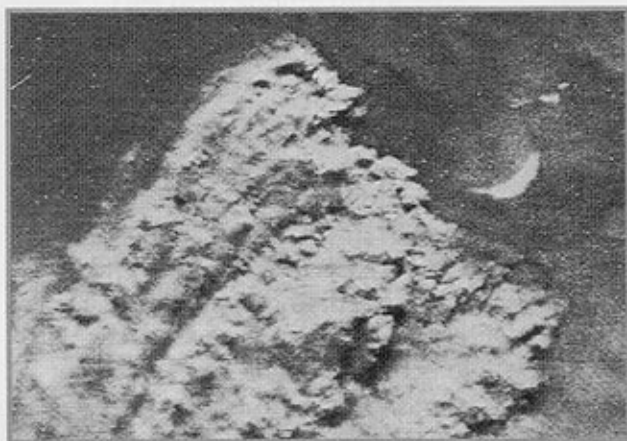
Even setting aside the questions of life, Mars is a fascinating planet, with vast canyons, volcanoes, dust storms, and evidence of flowing water in the ancient past.



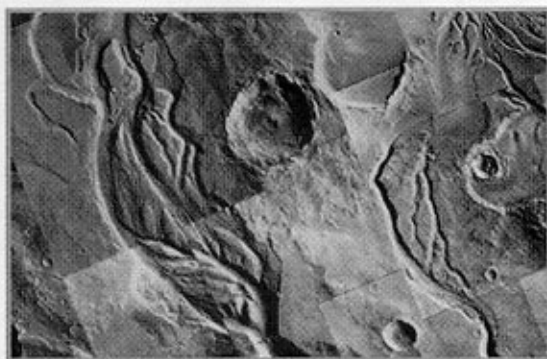
Olympus Mons is the largest volcano in the Solar System, 27 km high and 600 km wide.



Valles Marineris is a huge rift valley, longer than the distance from New York to San Francisco.

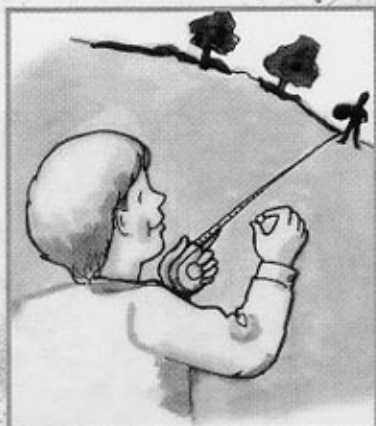


Huge dust storms periodically cover the entire planet.



Channels show evidence of flowing water in the ancient past.

Investigating Mars Can Help Us Improve Science Education



Mars is not only the focus of on-going scientific investigation, it also offers a wonderful opportunity to improve science education.

Your students will learn:

- fundamental concepts of Earth and space science
- skills of inquiry and investigation
- how to identify and control variables
- how to conduct an investigation and obtain a table of data
- how to construct graphs and describe relationships among variables
- how to discuss alternative hypotheses and base arguments on physical evidence
- how to design and build simple rovers
- how to gather information using computers and telecommunications
- how scientists and engineers work together to solve problems

Your students will do classroom experiments, model geological processes, ask questions, collaborate to find answers, analyze pictures of the surface of Mars, compare Earth and Mars, and confront their own misconceptions in Earth and space science. When NASA's current missions arrive at Mars, your students will use computers and the Internet to access live data and images of Mars to support your students' own investigations.

Most importantly, they will be deeply engaged in the scientific process — learning by doing, through an approach that emphasizes hands-on learning.

National Science Education Standards

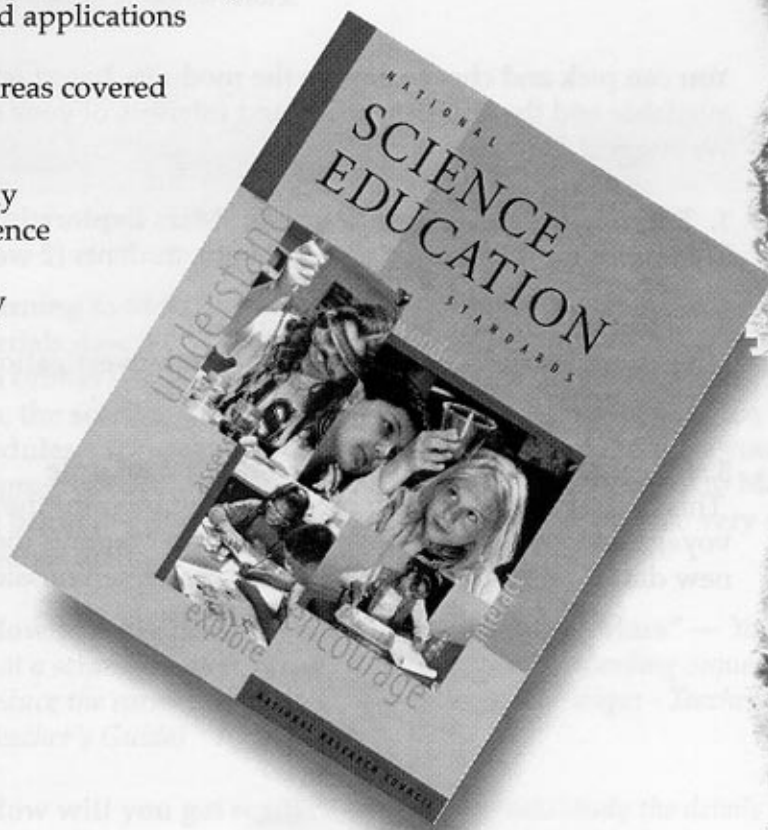
The National Science Education Standards provide national guidelines to help schools improve their science education programs by defining both content and process goals and by emphasizing hands-on experiential learning.

The Mars Education Program can help schools implement the standards in a creative, innovative and multi-faceted program. As recommended in the Standards, the Mars Education Program emphasizes:

- hands-on, inquiry-based learning
- an integration among the science domains
- use of technology to support student investigations
- use of graphs for data analysis
- real-world applications

The content areas covered include:

- astronomy
- Earth science
- physics
- chemistry
- biology



Middle School Goals

At the middle school level (grades 5-8), the Standards call for the following activities, all of which are part of the Mars Education Program:

- identify questions that can be answered through scientific investigations
- design and conduct a scientific investigation
- use appropriate tools and techniques to gather, analyze, and interpret data
- develop descriptions, explanations, predictions, and models using evidence
- think critically and logically to make the relationships between evidence and explanations
- recognize and analyze alternative explanations and predictions
- communicate scientific procedures and explanations
- use mathematics in all aspects of scientific inquiry

Overview of the Mars Education Modules

The Mars education materials are organized in modules. Each module contains a set of activities which relate to an over-arching theme. In each module, the activities progress from one to the next, enabling students to progress from introductory experiences to deeper understandings and more advanced investigations.

Some of the modules are ready now, others are in active development and will be released in the future. All will be reviewed and revised on an on-going basis, as we receive feedback from the teachers, and as new discoveries and new questions about Mars emerge as NASA proceeds with its ten-year planned exploration of Mars.

Selecting Modules

You can pick and choose among the modules, based on the time available and the abilities, needs and interests of your students. We suggest that you:

1. Begin with the Getting Started in Mars Exploration module

This lays a foundation for you and your students (2 weeks).

2. Select and implement a theme module

This provides classroom experiments and investigations focused on a single domain (6 weeks).

3. Select and implement a mission-based module

This helps your students understand and monitor the launch, voyage and arrival of a Mars mission, and prepares them to use the new data and images (4 weeks + activities when mission arrives).

The modules are organized in three groups:

Group 1 — Getting Started

The Getting Started in Mars Exploration module launches the program with background information and activities on Mars and Mars exploration. It consists of the "Teacher's Guide to Getting Started in Mars Exploration" and a student booklet called "Getting Started in Mars Exploration".



Grade levels

These materials have been used successfully in grades 5-12.

- *Getting Started in Mars Exploration Module*

Group 2 — Theme-based Modules

These modules deal with science themes that relate to Earth and Mars. For example, the Volcanoes module helps students understand how volcanoes form and how to recognize different types of volcanoes in images of Earth and Mars.



- *Grand Canyon of Mars*
- *Great Martian Floods and the Pathfinder Landing Site*
- *Volcanoes*
- *Search for Life*
- *... others to follow*

Group 3 — Mission-based Modules

These modules relate to specific missions to Mars, with activities to help students understand the engineering challenges, instrumentation and the scientific questions being investigated.

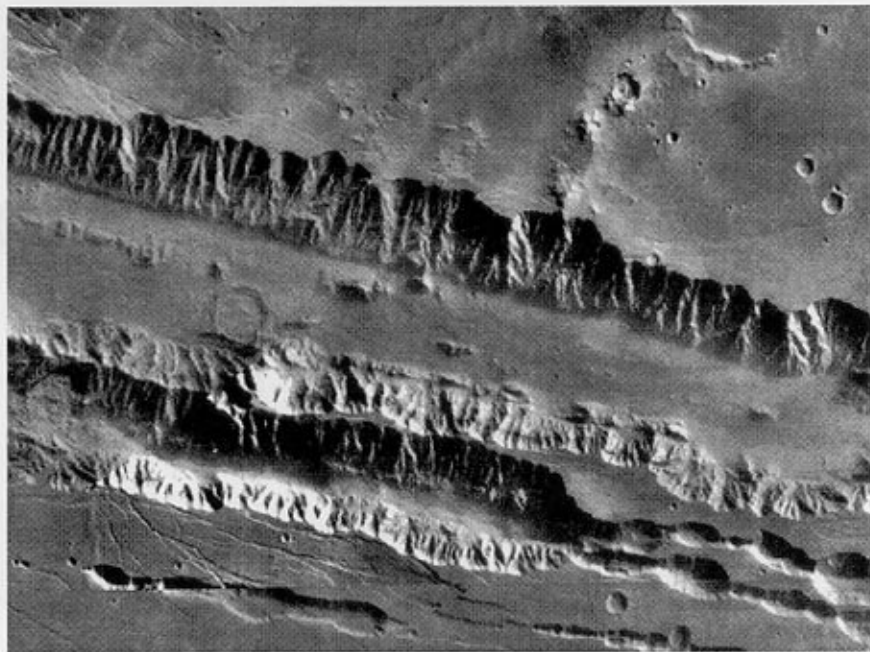


- *Mars Pathfinder*
- *Mars Global Surveyor*
- *... others to follow*

How is Each Module Organized?

Each module has a Teacher's Guide which presents background information, a set of activities and suggested resources. Some of the modules also have correlated student materials, such as a set of images relating to the module.

Let's look at the Grand Canyon of Mars module as an example.



Mars' Valles Marineris is the largest canyon in the solar system. In this module, students model some of the processes of canyon formation, like uplift and slumping. Then they analyze images of the surface of Mars to find evidence of these canyon-forming processes. In a case study, students develop hypotheses for the formation of Valles Marineris. At the end of the module, students prepare for upcoming missions which will provide new data to help answer some of the outstanding mysteries about canyons on Mars.

The Canyons Teacher's Guide has the following sections:

Background



The background information helps you understand some of the key concepts relating to the canyons on Mars. The background section also clarifies the hands-on and discovery-based approach to learning used in these activities.

Learning Activities



The learning activities are organized around themes. For example, one theme is "How is land affected by water flowing across its surface?". In the activities, students use a stream table to model the flow of water over a surface and study the resulting patterns. They look for similar patterns from rivers on Earth and look at images from Mars with similar patterns, leading them to the conclusion that water may have flowed on the surface of Mars in its distant past.

Case Studies



Case studies enable students to apply and integrate some of the key concepts in the context of a specific region of Mars. For example, Ares Vallis is the target location for where the Mars Pathfinder mission will land. In the Ares Vallis case study, students explore images of the region, recognize indicators of past flowing water, trace the valley from its source to its destination, and understand why scientists chose Ares Vallis as the Pathfinder landing site.

Resources

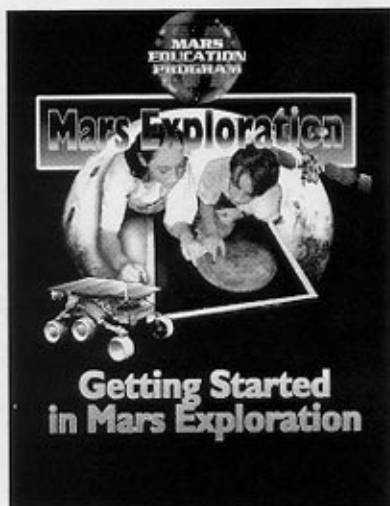


We recommend several key resources to help you and your students in your learning and investigations. Resources include Mars maps and images, posters, books, and Web pages on the Internet. The resource guide includes detailed ordering information. These resources will also support your students in continuing their investigations after they complete the activities in this module.



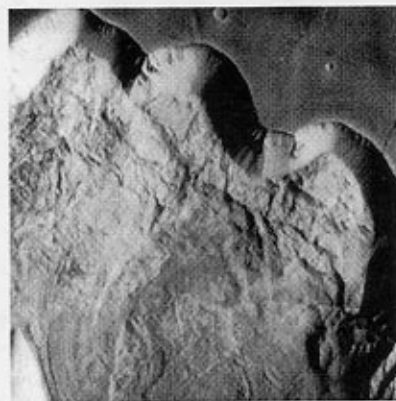
Student Materials

Each module has student materials, the nature of which varies from module to module. For example:



Mars Exploration Student Guidebook (Getting Started in Mars Exploration)

Getting Started in Mars Exploration lays the foundation for students through a series of activities, images and background information on Mars and Mars exploration. It is highly visual and engages students in classroom experiments and Mars image analysis. It also starts the use of a Student Mars Research Journal for students to record their observations, data, thoughts and questions for further research.



Student Image Set (Grand Canyon of Mars Module)

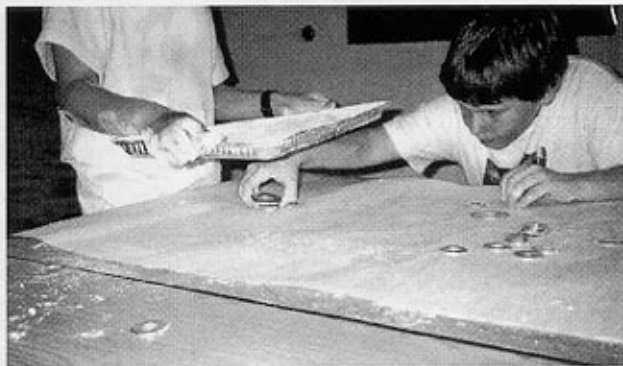
For the Grand Canyon of Mars module, the Student Image Set provides you and your students with a set of maps and photos of the surface of Mars. Students use these images as they pursue their investigations. We recommend that you get one set for each group of two or three students. This enables each student to examine the images closely and supports dialogue and collaboration about the images.

3 Types of Learning Activities

Each module has an integration of three types of activities:

Type 1 — Classroom Experiments

Students do hands-on experiments that model processes that occur on Earth or Mars. These inquiry-based experiences build understanding and lay the conceptual and experiential base for other activities.



Type 2 — Mars/Earth Comparisons

Students apply their understanding to situations on Earth and Mars. This helps students bridge the gap from their local environment to distant Mars.



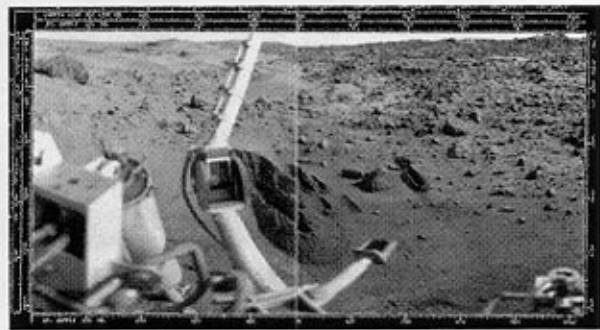
Mars Image



Earth Image

Type 3 — Real Data & Images from Mars

For now, students use data and images from previous missions to Mars. In the future, when NASA's new missions arrive at Mars, students will use the Internet to see the data and images at almost the same time as scientists, enabling your students to experience the excitement of scientific discovery as it happens.



NASA's Mars Missions

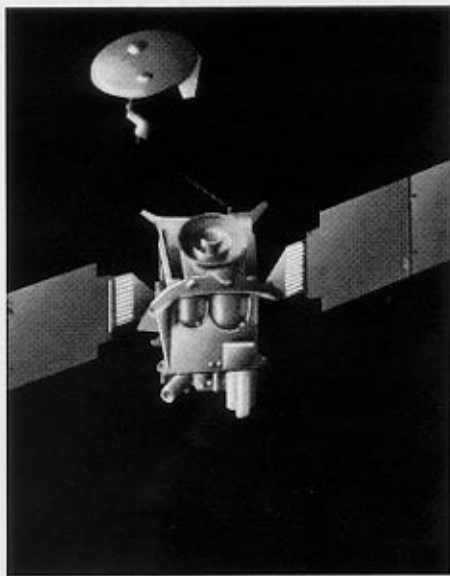
NASA is implementing an ambitious ten-year series of missions to Mars, each with specific science research objectives. New missions will be launched every 26 months, when Earth and Mars are correctly aligned for efficient travel. All of these are robotic missions with both orbiters and landers.

You and your students will be able to use the Internet and World Wide Web to access data and images from these missions, essentially at the same time as scientists see them. Preparing your students to understand what these new missions are about and preparing them to understand the data and images are important elements of the Mars Education Program.

For more detailed information, refer to the Getting Started in Mars Exploration student book and the World Wide Web (web addresses on the next page).

Jet Propulsion Laboratory
NASA's Jet Propulsion Laboratory (JPL) manages the Mars Missions. JPL is based in Pasadena, California, and has been at the center of most of the historic planetary exploration missions of the past three decades. JPL has a strong commitment to education, and has overall responsibility for NASA's Mars Exploration Education and Public Outreach Program.





Mars Global Surveyor

Mars Global Surveyor is an orbiter, which has a high resolution camera, Laser Altimeter, Thermal Emission Spectrometer and other instruments to study Mars from orbit.

Web address for more information:

<http://mgs-www.jpl.nasa.gov>

November 6, 1996 —	launch
September 1997 —	arrival at Mars, begins to stabilize orbit
March 1998 —	orbit stabilized, begins to send images and data



Mars Pathfinder


Mars Pathfinder will land on the surface of Mars. It has a camera, weather instruments and a robotic rover which will explore the area around the lander. It will be launched shortly after Mars Global Surveyor, but will go on a faster route and will arrive before Surveyor.

Web address for more information:

<http://mpfwww.jpl.nasa.gov>

December 4, 1996 —	launch
July 4, 1997 —	arrival and landing on Mars (target date)

Getting Started

- 
1. **Read this Teacher's Implementation Guide** -- It gives you the background on the educational design of these materials and helps you plan for the year.
 2. **Read the Getting Started in Mars Exploration student book** -- While written for students, it is another way to learn about Mars and NASA's up-coming Mars missions.
 3. **Decide which modules you will do** -- Based on the time available and your students' interests and abilities, you might begin with the Getting Started module, and then select one or more of the other modules.
 4. **Order supplies** -- At the end of the Teacher's Guide for each module is a list of the materials you will need. All are either commonly available or inexpensively available through mail order.

Learning About Mars

You will certainly learn along with your students. Each module has background information, and the learning activities are just as effective for teachers as they are for students.

You may also be bitten with the "Mars bug" and get quite interested in learning more on your own. Each module has a resource list for further information, and you will find books about Mars and other planets in almost any bookstore. Web pages on the Internet are also an excellent resource. Begin with the home pages for Mars Global Surveyor and Mars Pathfinder (see previous page). These are updated regularly and will point you to many other web resources.

The more you learn, the better you'll be able to facilitate the activities, and the better you can share your own enthusiasm, the heart of all successful teaching.

Transforming Science Education



Guest Essay
by
Dr. Meredith Olson
Mars Program Educator

The ultimate goal of JPL Mars Exploration Education is to use the unprecedented adventure of going to Mars as a tool for the improvement of science education.

The Mars adventure will produce information. The Mars education modules promote UNDERSTANDING.

We need to consider the difference between information and understanding. People often tell about Mars. JPL's Mars education modules promote understanding about Mars.

We know a revolution in science instruction is unfolding. Three stunning publications focusing on theoretical considerations underlying the science reform movement provide direction for our efforts: *Benchmarks for Science Literacy*, *Science for All Americans*, and *National Science Education Standards*

Benchmarks points out that current methods of teaching planetary science need improvement.

It states, for example, that middle-school students who are taught by traditional means are unable to coherently explain the causes of volcanoes and earthquakes. *Benchmarks* also indicates that most of the research in how students learn science has been done in physics, in ideas related to the universe, and in forces and motion. Very little has been done on how students come to understand the processes that shape the Earth or other planets.

Science for All Americans stresses that learning is not necessarily an outcome of teaching. Many students understand less than we think they do. Sound teaching usually begins with simple, but ingenious questions to assess students' understanding of particular topics. This begins an extended investigation that provides small but multiple experiences to

U N D E R S T A N D I N G

Misconceptions

Students bring every-day common-sense misconceptions with them to the classroom. Left unexamined, new information will be forgotten in favor of these prior tenaciously held impressions.

Experiences

A sequence of juxtaposed experiences provides the opportunity for students to discover patterns in data gathered from seemingly unlike activities.

Data Collection

Rather than having committees doing separate projects, teams of students do the same lab. Class discussion reporting data from each lab provides enough replication of the procedure to create a scattergram graph. Rather than "teacher-tell" methods, the scattergram of data they have each personally experienced convinces students of the reliability of the findings.

Transfer

After students have gained understanding and strategies for thinking about specific concepts, presenting them with a unique feature of Mars or a space engineering device produces exclamations of awe and excitement.

broaden students' thinking.

Student activities matter. Rather than telling students answers to memorize, we need to provide visual, auditory, kinesthetic, and literal experiences which students represent in multiple ways. We must take interest in what a child notices and does to transform and represent observations. How do we provide experiences that train the eye to notice what is subtle and significant? Looking is an activity. Seeing is an achievement. Once we see something, we must be allowed to speak about it in order to stabilize the image. Classroom discussion allows us to make meaning from our observations in large measure because of different perceptions by students. Our senses perceive the world, but our debates allow us to construct meaning of what we see.

Our goal is not just to teach about Mars. Our goal is to teach habits of mind. Very often our lessons do not start with Mars but bring Mars science and engineering in at appropriate times when students are primed to make discoveries. We seek to promote the habits of mind that underlie science literacy, science reasoning and, I would add, engineering ingenuity. So, our fundamental task is: how do we help students develop these habits of mind as they make meaning of Mars data? How do we engage their interest? How do we engage their ingenuity? How do we inspire their confidence and joy in their own reasoning abilities? How do we teach without telling? We believe that a scientifically literate society is built from students' exposure to carefully crafted lessons that reveal their misconceptions and which engage them in science process activities to reconstruct their understandings.

We have a window of opportunity both in space science and in education.

1. We have the unprecedented Mars exploratory missions.

2. We have a surge of interest in the improvement of science instruction.

Both will unfold over the coming decade. The Mars curriculum project provides a high-profile vehicle to promote teaching for scientific understanding.

Science Lesson Conceptual Framework

What are the essential elements of a good science lesson?

How do we teach for understanding?

Good lessons have four components:

1. The introductory question: Beginning lesson sequences with a self-assessment question is the pivotal requirement. This is a question that challenges students to confront the extent to which they do or don't understand a concept. All students should be required to answer this question in writing before any introductory class discussion begins. In fact, this question serves as the orienting vehicle. It attracts their attention and usually generates interest in the topic. The teacher collects the papers without commenting and never returns them. Retaining papers deprives students of "closure" that allows them to remove the issue from their mind. They remember their written answers better if the teacher continues to hold them.

Students often bring misconceptions, sometimes based on common-sense, to the classroom. The theories are those that we all make as part of making sense of what happens around us. For example: ice floats because it

has air in it. These misconceptions are strongly held. Simply telling students that their conceptual understanding is wrong or incomplete is not sufficient to eradicate the misconception even when we tell them the correct explanation. In fact, since these misconceptions allow us to deal with everyday affairs with some sense of competency, they seem to be tenaciously retained so as to avoid calling into question our ability to act effectively in everyday life. Grading such deeply-held ideas may somehow make students "science shy" as they become aware that they don't understand many things. In addition, simply telling them the correct answer doesn't work - students soon revert to strategies that use the same misconception.

The introductory question is crafted to appear simple and self-evident. It should not reveal discoveries that students will have the opportunity to make in the forthcoming lessons. (Each lesson should build upon the last until the wholeness of the idea under consideration dawns on students at the end of the unit.) It is imperative that subsequent activities provide opportunities to help students overcome misconceptions. They should confront the contradictions between their assumptions and physical phenomena. Once they perceive the inconsistencies and accept the challenges of resolving them, it is more likely that misconceptions will be corrected.

2. Lesson sequence: The set of lesson activities must contain concrete materials for students to manipulate. Essential characteristics of lesson activities include enabling students to notice similarities, contrast attributes, construct data tables, and graph to reveal hidden likenesses and predictability.

Having a sequence of lessons is essential because of the nature of human mental

processes. We recognize patterns, but not from one example. If students are to truly comprehend the scientific process, they should strive to extract patterns of scientific concepts from juxtaposed events. Fortunately, children enjoy extracting patterns. We notice students endlessly discussing similarities and differences concerning baseball cards, magic cards and sporting events. A science lesson sequence capitalizes on this attribute of human nature and focuses student attention on a constant stream of little laboratory activities from which they may be able to detect patterns, relationships, and likenesses between unlike appearances. This stream differs from the "normal" stream of daily life experiences in that it deliberately highlights patterns, relationships and misconceptions. By experiencing a concept in different settings, we form connections among ideas and build the web of relationships by which concepts acquire meaning. When examining the villi of the gut, students have said, "Gee, that is just like when we put foil fins on metal rods to keep them cool." It doesn't matter which science content is chosen. It is not that the content is unimportant, but rather, which content is unimportant. Although we know students will improve in their ability to answer the original pre-assessment question, the answer is incidental to development of deeper understanding of key science concepts and the process of knowledge construction.

Certain key sequences enhance the discovery of concepts more successfully than others. The teacher must understand the potential of the activity sequence and must keep returning the discussions to the central thread. A fundamental tenant is that the teacher will refrain from evaluating work as right or wrong, but will draw students' attention to the implications of the data and encourage them to make their own conclusions. For example, the teacher may say "I notice most of our data

clusters here, but this point is over there..." In order to create interest, great attention must be paid to the flow of materials being presented. Within this vision, the teacher is free to focus on what students are actually saying in their laboratory conversations. This allows the teacher to assess whether to jump ahead to future activities and return to the contemplated series at a later time. The teacher must determine which activities a given class is capable of and which should be done for expediency. The degree of change in the stimulus situation must be closely matched to the learning styles and abilities of each classroom of students. The experiences can't be too dissimilar or no patterns will be found. The activities can't be too similar or no pattern categories will be noticed. Students must be just a little uncertain about what will be discovered next. Cognitive change takes place under a relatively narrow range of uncertainty. The role of the teacher is to introduce just the right amount of variability and uncertainty into the subject.

3. Data treatment: It is important that students feel they own the intellectual process going on in the classroom. As often as possible, a regression line of pooled data should be the criteria for validating correctness. This frequently requires cooperative activity as all teams in the class contribute data to the statistical accumulation. The public sharing of data provides regular feedback and facilitates frequent reflection about explanations and predictions.

Students must feel they have control over designing each lab activity. As they implement the activity designed in class discussion, they must figure out the details of how to set up their own equipment to perform procedures. They must measure and record data while watching the event happen. The process becomes a personal venture for students only

when they record lab directions and data in their own lab notebooks. A lab notebook is very different from a lab report. A lab notebook is an "in process" document. Collectively designing the format in which the data will be written is central to students' understanding their task. The expediency of using photocopied data tables or pre-constructed coordinate systems on which to enter data points deprives students of participation in this crucial part of the lesson. Lessons should examine continuous independent and dependent variables and use the terms gently and appropriately as students become comfortable with designing experiments. Students benefit from using small sections of grid paper taped into their lab notebooks and discussing how to distribute continuous variables across the space available on each axis. Disagreement in results can be a springboard for discussions that empower students to craft revised experiments while maintaining the interplay of events that promote the discovery of fundamental science concepts.

4. Post-assessment: A related thought puzzle in a new context enables students to generalize developing understandings. Success of the process would be measured by student enthusiasm for considering the new situation and self confidence such as saying, "Hey, I think I figured that out!" Although reasoning would not be graded, a teacher could contrast the improved reasoning used in the reply with the individual's response on the pre-assessment.

Much of the Mars information is new. After students have gained understandings about specific concepts, presenting them with an image of a unique feature of Mars or a space science engineering device produces exclamations of awe and excitement. They are energized by their own powers of deduction as they generalize their understandings of

planetary science. Students find watching planetary rovers navigate remote sites more engaging after attempting to create their own rover. Designing methods of time-delay navigation communication reveals the technical difficulties of the task and leads to enthusiastic appreciation of planetary projects which have solved the task elegantly. One is generally much more interested in and appreciative of the devices of others when one has already tried to do the task independently.

The posing of a seemingly unrelated question that embeds the same fundamental science concept in a new context is both a learning experience for students and an assessment tool for the teacher. Perhaps the most telling observation will be students' willingness to examine the new question thoughtfully. Additionally, we frequently see the inclination of students to approach the subject by identifying variables and considering effects of controlling and varying each in a systematic manner. The process of their analysis of the puzzle is as important as their recognition of the underlying science concept.

The current interest in science improvement points out the impossibility of real understanding through lectures. The only time such discourse communicates is if you already understand the underlying concepts. How can you explain: swimming to one who has never been in water, a blizzard to one who has never experienced snow, sight to the blind, basketball to the disabled, or riding a bicycle to one who has never seen machines of any type?

So, as we develop lessons we have four tasks:

1. What is the opening question of the lesson?
2. What series of childlike experiences highlight likenesses among seemingly unlike events so students come to discover a concept?
3. What modalities of communication and data reporting are appropriate to various ages and learning styles so as to avoid "teacher-tell"

behavior?

4. Which Mars image or space engineering device best relates to the concept just learned?

We have a daunting challenge before us.

JPL scientists have exciting information and our job is to make this information exciting for middle-school audiences. We are told that what is taught and how are frequently and persistently contrary to the suggestions of national educators about what should be happening in science classrooms. Research tells us that we are the sum of our experiences. Conversely, we cannot become what we have not experienced. The activities in the JPL Mars Exploration Education modules offer experiences that middle-school children enjoy and which promote their understanding of fundamental science concepts. The use of such lessons can change the "severe, terminal boredom" often exhibited by middle-school science students into self-confident appreciation and excitement over the forthcoming adventures to Mars.

Dr. Meredith Olson is the Mars Program Educator for the Mars Exploration and Education Program. Based on her expertise and experience as a science teacher, she has a strong voice in shaping the educational philosophy and learning activities in the Mars Education modules. She is the Middle School Chairman and Science Education Specialist at the Seattle Country Day School, in Seattle, Washington.

